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ABSTRACT

This document reports on a study of the feasibility of a procedure for evaluating an instructional program. The instructional units evaluated were professional education courses which were structured around performance objectives and utilized a model similar to the Personalized System of Instruction (PSI). Data were collected in four phases; instruments used included the California Psychological Inventory, the Tennessee Self-Concept Scale, mastery tests related to the objectives, formal evaluations of student teaching performance, and participant evaluations of the experience. Two hundred eighty-one variables resulted for each teacher in the sample of 25. Relationships among variables were determined by logical and correlational analyses. Data were submitted to four types of regression analyses; the analyses were interpreted, indicating that the goals of the project were met and a decision equation was derived. (SD)

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Mathematical Equations for Curriculum Decision-Making: An Application of Regression Analysis

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Abstract

This project was conducted to mathematically integrate longitudinal data obtained from secondary teachers into a curriculum decision procedure. A four phrase data collection procedure was implemented into a secondary level teacher preparation program to provide the variables for assessing the quality of various program components. Regression analysis was utilized to determine the relation between criterion and independent variables related to two of the nine instructional units. Regression models accounting for 44% and 68.5% of the variance were found to occur for the self-analysis and performance objectives instructional components, respectively. Further analyses provided numerical values to determine the effectiveness of each instructional unit.

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Comprehensive curriculum evaluation is a very complex process. This assertion is reasonable for no other reason than the variety of variables, such as the following, that must be attented to: learner achievement, interpersonal communications, power structures, school organizational climates, variety and quality of instructional resources available, and societal norms concerning education. With such a variety of concerns vying for attention, an evaluation project must define evaluation and differentiate the goal from the functions if the evaluation process is to contribute to the curriculum under scrutiny. In an oft-cited work, Scriven (1967) described evaluation as a methodological activity in the following manner.

> "The activity consists simply in the gathering and combining of performance data with a weighted set of goal scales to yield either comparative or numerical ratings and in the justification of (a) the data gathering instruments, (b) the weighting and (c) the selection of goals." (p 40)

Expanding on this definition, Scriven stated that evaluation should not only collect and analyze data, but should make judgments and report these judgments publicly.

Another significant definition of evaluation was developed by the Phi Delta Kappa National Study Committee on Evaluation (Stufflebeam, Foley, Gephart, Guba, Hammond, Merriman, Provus, 1971):

> "Evaluation is the process of delineating, obtaining and providing useful information for judging decision alternatives." (p XXV)

In contrast to Scriven, the authors of this definition emphasize that evaluation is a continuing process which provides information that should guide decision making, not produce judgments. The authors of these respective definitions agree that evaluation is a process whereby data are gathered for the purpose of decision making, but disagree on who is to make the decisions. The issue of <u>who</u> makes the decisions may not be central if the scope of the curriculum evaluation is limited to a small scale project and the curriculum developers are also serving as evaluators. When curriculum development and subsequent evaluation of the curriculum occurs in educational settings whether at the local district or building level, or within higher education at the college or department level, the developer and evaluator roles may be assumed by the same individuals. It is assumed that under these circumstances the curriculum is being designed for a particular educational setting with no grandiose plans for marketing the curriculum regionally or nationally. Under these conditions, decision making in regard to the effectiveness of instructional components is a viable goal and violates neither Scriven's nor the PDK committee's formulations of the concept "evaluation."

With an evaluation goal in mind, attention must be directed to the functions of the evaluation process. These functions may be directed either to the development, execution, and implementation of a curriculum or to the political and economic support for the curriculum (Zais, 1976, p 377). Because of the different emphases that are possible, it is difficult to develop a single generalized model for curriculum evaluation. On a positive note however, numerous conceptual models outlining various types of evaluation have been advanced during the past decade. For example, the Countenance Model (Stake, 1967), Formative and Summative Evaluation (Scriven, 1967), the Modus Operandi Method (Scriven, 1974), the CIPP (Content, Input, Process, Product) Evaluation Model (Stufflebeam, et al, 1971), the Discrepancy Model (Provus, 1971), and the Center for the

Study of Evaluation (CSE) Model (Alkin, 1974) are among the more familiar models. These models identify critical decision-making points along the continuum of processes occurring in curriculum development, particularly, the development sequence championed by Tyler (1950) and sustained by Taba (1962).

Once a model is selected or created from the theoretical constructs provided by the various models, the evaluator is faced with pragmatic issues of identifying appropriate instrumentation, selecting the sample, and analyzing the data. In his definition of evaluation, Scriven refers to the issue of combining data with weighted goal scales to produce numerical ratings and to the justification of those "weightings." This weighting construct is intriguing and should influence data analysis significantly. Weighting the data sources in terms of their relative importance prior to data collection appears to be what Scriven is suggesting when he discusses the primary, secondary, and tertiary effects of the curriculum on the various actors affected by the curriculum. The effects of the materials on the learners' mental and nonmental abilities and attitudes are labeled as the primary effects of the curriculum. Secondary effects of the curriculum affect those individuals who implement the curriculum, namely, teachers, teacher aides, supervisors, while tertiary effects are those effects on the school or other students brought about by learners or teachers who exhibit the primary or secondary effects (Scriven, 1967, pp 74-82).

If primary effects such as achievement data, attitude data, and subsequent follow-up information are obtained from learners, should all of these data sources have equal weightings? Moreover, if secondary effects, such as supervisor and/or principal ratings are collected and combined with the primary effects, what "weights" should these data sources assume? Rather than assign decision weights _a priori_, this project was undertaken to develop a procedure whereby various data were collected, treated to determine decision weights, then combined in a mathematical decision equation. Specifically, the development and implementation of a procedure to empirically weight the data was an ancillary goal of this project, while the primary goal was the mathematical integration of weighted data to evaluate the quality of instructional components in professional education coursework.

Data Source

The institutional setting for this project was a Land Grant University accredited by the Southern Association of Colleges and Universities and the National Council for the Accreditation of Teacher Education. Thirty-five secondary level teachers who had recently completed supervised student teaching at the secondary level and the related professional education coursework constituted the final sample for this project. The diminutive nature of this sample would be of greater concern had the goals of this project been other than to illustrate the feasibility of an evaluation procedure.

The instructional units evaluated were components of the professional education coursework which immediately preceded student teaching. Six semester hours of credit were awarded to the candidate for successfully completing the eighteen instructional units contained in this coursework. Each instructional unit was structured around performance objectives, with seventy-seven objectives existing for the total program. Topics including discipline, performance objectives, test construction, interpersonal communication, unit planning, teacher/law, teacher self analysis, instructional modes, and individualized instruction were among the topics examined.

The instructional model employed during this coursework enabled candidates to remediate and retest objectives not achieved on the first assessment. Generally, this instructional model embraced the tenets of the Personalized System of Instruction (Keller, 1968) with remediation consisting of self-study and tutorial assistance available from the course instructor. Grade credit for the coursework was awarded to the candidate on the basis of criterion performances on the various unit tests, regardless of whether remediation and retesting were necessary.

Data Collection

A four phase collection plan was developed and gradually implemented to provide the data necessary for assessing the quality of the program. Phase one consisted of personality measures, namely, California Psychological Inventory (1965), Tennessee Self-Concept Scale (1964), being administered to teaching candidates before instruction commenced. Based on results from earlier efforts, the investigator felt various subscales of these measures would serve as indicators of candidate success in the various instructional components (Denton and Stenning, 1973).

Monitoring teaching candidate progress during the professional education coursework was the primary function of phase two of the plan. Information concerning the number of trials necessary to reach mastery for each objective, the number of objectives actually mastered, and student perceptions of the quality of the instructional components were determined at the conclusion of each component (Denton and Bennett, 1975).

These data provided diagnostic information for adjusting each teaching candidate's instructional program and simultaneously provided the dependent variable for regression procedures used for quality control determination of the curricular components.

Student teaching performance was the focus for phase three of the collection plan. Included in this phase was a procedure to assess student mastery of teaching behaviors related to the objectives contained in the instructional modules completed prior to student teaching. Formal evaluation forms were used which permitted the professional staff, i.e. cooperating teacher and university supervisor, to rank and record student teacher performance on classroom behaviors and instructional skills. These behaviors were directly related to the enabling objectives in the general methods and curriculum courses. Information on the degree of knowledge transfer into observable teaching behaviors provided the instructional staff with another measurement of the effectiveness of the instructional components that could potentially be combined with other data to render curricular decisions concerning the preparation program.

Phase four of the plan requested first year graduates to provide their perceptions of the preparation program. Questionnaires were supplied to recent graduates after one semester of teaching. This follow-up procedure permitted the collection of perceptions of first year teachers, tempered by actual classroom experiences, regarding the quality and value of the instructional components in the preparatory program (Rosser and Denton, 1977).

A continuum divided into five intervals was the basic format for the rating scales and perception instruments employed throughout phases three and four of the collection plan. The uniformity of item format among these scales resulted in comparable values, thereby eliminating the need to transform raw scores. Descriptive validity of these instruments was addressed by comparing the items on each instrument with the performance objectives in the coursework being evaluated. A logical relation among the items on each instrument and to one or more performance objectives was required for the item to be retained. In addition, a reliability estimate, the Cronbach alpha coefficient of .89, was determined for the follow-up instrument.

Data Analysis

Two instructional components, namely, performance objectives and self analysis skills were selected to demonstrate the four statistical techniques used to yield decision weights and ultimately the respective decision equations. Given the nature of the collection plan, a large number of variables (281) resulted for each teacher in the sample. Logical relations between variables and sets of variables reduced the number of potential predictors substantially. However, the number of logical predictors for the criterion (candidate achievement measure/ instructional unit) always exceeded the limit prescribed by the sample size given regression techniques. Consequently, correlation coefficients were determined among the variables logically related to the achievement score for the instructional component being analyzed. The procedure yielded seven potential predictors for each of the components considered.

The second statistical treatment involved the RSQUARE procedure from the Statistical Analysis System (SAS) (Barr and Goodnight, 1972).

This procedure performed multiple regressions to the dependent variable with the seven predictors identified in the preceding step. Optimal variance (R^2=.685) was accounted for by five of these variables for the instructional component dealing with performance objectives:

CT18 - Cooperating teacher rating: relation between test-objectives

US18 - University supervisor rating: relation between test-objectives

.1CM - CPI scale (communality) X.1

CT35 - Cooperating teacher rating: content organization

I10 - Follow-up importance rating: lesson planning

Four variables accounted for the variance (R^2=.44) of the component on self-analysis skills:

.1SA - CIP scale (self assurance) X.1

CT30 - Classroom teacher rating: classifying questions

I8 - Follow-up importance rating: leading discussions

I19 - Follow-up importance rating: using different instructional modes

These respective predictor-dependent variable sets for the performance objectives and self-analysis skills instructional components were subsequently placed in prediction models and analyzed by a stepwise regression analysis procedure called REGR in SAS (1972) Results of these analyses are presented in Tables 1 and 2.

Insert Tables 1 & 2

The F values for both regression models were determined to be significant, i.e., F=13.02, p. 0001 (performance objectives), and F=4.73, p. 006 (self-analysis skills). The regression procedure for each prediction model produced partial sums of squares for each decision variable which were employed as decision weights for the variables in the resulting decision equations while the algebraic sign of each decision weight was obtained from the sign of the beta value for that variable. Substituting these values into a linear expression, the decision equation for the performance objective component became:

$$\text{Min } Y \leq 1.11\ \overline{X}_{CT35} + 1.01\ \overline{X}_{I10} + 1.40\ \overline{X}_{US18} - .65\overline{X}_{CT18} - .32\overline{X}_{.1CM}$$

and the decision equation for the self-analysis skill component assumed the form:

$$\text{Min } Y \leq 1.26\overline{X}_{CT30} + .86\overline{X}_{.1SA} + 1.55\overline{X}_{I19} - 1.34\overline{X}_{I8}\ .$$

Substituting the mean values (Table 3) for each variable in each equation and performing the arithmetic operations yielded 11.48 for the performance objective instructional component and 8.27 for the self-analysis skill instructional component. These values were compared with criterion values (Min Y) calculated for each equation based on maximum values for each decision variable multiplied by a .85 accomplishment factor for the group of teachers. The resulting criterion values for the performance objectives component was 11.44 while the cut-off value for the self-analysis skills component was 8.77.

The calculated value for the self-analysis component, (8.27) did not reach the criterion value of 8.77. Conversely, the calculated value (11.48) for the performance objective component exceeded the cut-off value of 11.44.

Insert Table 3

Discussion

A cursory examination of the results of these analyses suggests that the goals of this project were achieved. However, a number of assumptions, observations, and decisions were made which heretofore have not been addressed. First, curriculum evaluation as practiced here assumed the performance objective to be the basic organizational element in curriculum design. Instructional activities and assessments were directly related to performance objectives in the various instructional components, allowing these curricular elements to be isolated for evaluation.

Second, another assumption of this project was that candidate achievement data obtained from criterion-referenced tests could serve dual functions. One function of the data was to provide course progress indicators for the candidate's course grade, while the second function was to evaluate the effectiveness of instructional components related to particular objectives. In the case of student progress, assessment data were treated idiographically, that is, the candidate was the unit of analysis. However for the second function, program evaluation, the achievement data were treated normatively. This data set was thought to be most appropriate for the criterion variable used in deriving the weights for the decision equations because of the relation of these data to the instructional components and because of the careful attention and thought afforded the tests by the candidates. Moreover, Scriven's position on payoff evaluation (1967, pp. 59-62) lends credence to the application of an achievement data set as the criterion variable in the decision process.

Third, considerations for weighting the data ranged from intuitively assigning decision weights to devising a multi-step procedure which provide empirical justification for the assigned weights. Since the data collection procedures employed yielded numerous variables and the criterion variable was known, regression procedures were considered viable for quantifying the "weighting" process. Regression procedures are relatively free of operational assumptions, and may be readily employed given appropriate computer software, namely, user oriented statistical packages. Further, stepwise regression analysis yields two necessary elements in weighting the data:

a) the <u>partial sums of squares</u> value indicates the unique contribution of a variable to the overall variance in the regression model (Draper, Smith, 1966).

b) beta values for each variable, being vector quantities, represent both spatial orientation and magnitude for that variable with respect to the axis of the linear model produced.

Fourth, the generalized first order linear equation, $Y \text{ min} \leq \sum_{n=1}^{i} I_{xi} \overline{X}_i$, for evaluating the curriculum components resulted after considering whether transformations of the data sets (reciprocal, logrithmic, square root, and higher order models $[X^n]$) would enhance the decision equations. For these adjustments, the appropriate choice should be made on the basis of previous knowledge about the effect of the transformation on the variable. Usually, this condition is not known, for example: What is the instructional significance of using the natural logarithm ($\ln^e$) of a supervisor's numerical rating? Or how does this transformation influence the statistical analysis? These questions illustrate potential unknown effects of possible data transformations. In addition, the linear regression which yields the decision weights will not be statistically significant if the first order model digresses too far from linearity. Because of these observations, the decision was made to use the generalized expression with first order variables rather than resort to data transformations which would increase the complexity of the equations.

Fifth, although high-inference instruments were used in the collection plan, especially in phases three and four, it was assumed that data obtained from observation scales completed by student teaching supervisors and self-reports from former teaching candidates would provide stable and valid data for curriculum evaluation. In support of this assumption, Turner (1974) has suggested that the perspectives of recent graduates, tempered by the real world, are important data sources for evaluating the effectiveness of teacher preparation programs.

Finally, the relations of decision variables to the criterion were limited to the range of observations from which the decision weights were derived. The significance of this observation is that each time a curricular component is to be evaluated a unique decision equation must be developed.

In view of these assumptions, observations, and limitations of the evaluation process, one may question whether the project goals were actually achieved. To resolve this concern, reconsider the primary goal of the project and the steps taken to accomplish it. Essentially, the goal called for the mathematical integration of weighted data into decision equations for curricular evaluation. The following procedures were developed to accomplish this goal:

1) Identifying potential decision variables - This step is accomplished by determining correlation coefficients between the array of predictor variables and the criterion variable. Variable selection is based on the magnitude of the coefficient and the logical relation between the variables.

2) Selecting decision variables - A forward regression procedure incorporating the variables identified in step one is performed with the criterion variable to determine the "optimal combination" of decision variables. This "optimal combination" depends on the axiom, maximum variance with minimum variables.

3) Determining decision - weights - A stepwise regression procedure is conducted with the decision variables identified in Step 2. This procedure yields an overall F-test for the regression model, as well as F values for each decision variable in the model. If the overall F value is not significant, indicating the variance accounted for by the decision variables is slight or the regression is not linear, the procedure to determine a decision equation terminates for the instructional component under consideration. Conversely, if the overall F value is significant, the decision weight for each variable assumes the numerical value of the partial sums of squares for that variable, and the directionality (arithmetic sign) of the corresponding beta value.

4) Incorporating decision weights into a decision equation - The decision weights resulting from the stepwise regression analysis are then substituted into the general expression

$Y\ min \leq \sum_{n=1}^{i} I_{xi}\ \overline{X}_i$ to complete the decision equation.

5. <u>Solving decision equation</u> - The expression on the right side of the equation is solved by adding the products of the respective decision weights - variable means together. The expression Y min is determined in much the same manner except maximum values replace the mean values. The resulting sum is then multipled by a .85 accomplishment factor. This value was selected as the accomplishment factor because of potential positive bias on rating scales and perception instruments, and the intuition that an instructional program should not be considered effective unless it is compared with a rigorous but attainable standard. Interpretation of the results of these calculations depend on the relative magnitudes of the solutions; if the value of Y min exceeds the value on the right side of the expression revision of the instructional component should be seriously considered.

That these steps represent a functional process depends on whether implementation has occurred and yielded results which are meaningful. Results of the evaluations included in this paper have illustrated that indeed these steps are feasible and do provide empirical support for curriculum decisions. In essence, this project has operationalized the integration of longitudinal data sets into a generalized mathematical expression for rendering precise curricular decisions.

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Table 1

Stepwise Regression Procedure for the Dependent Variable:
Learner Achievement on the Performance Objectives Instructional Component

Source	DF	SS	MS	F	Prob	R^2
Regression	5	5.989	1.198	13.019	.0001	.685
Residual	30	2.760	0.092			
Total	35	8.750				

Source	Partial SS	B value
CT18	0.650	-0.276
US18	1.402	0.429
.1CM	0.323	-0.051
CT35	1.106	0.344
I10	1.014	0.162

CT18 Cooperating Teacher rating: test-objectives relation
US18 University Supervisor rating: test-objectives relation
.1CM CPI Scale: Communality X.1
CT35 Cooperating Teacher rating: content organization
I10 Follow-up importance rating: lesson planning

Table 2

Stepwise Regression Procedure for the Dependent Variable:
Learner Achievement on the Self-Analysis Skills Instructional Component

Source	Df	SS	MS	F	Prob	R^2
Regression	4	8.175	2.044	4.727	.006	.441
Residual	24	10.377	0.432			
Total	28*	18.552				

Source	Partial SS	B value
.1SA	0.861	0.055
CT30	1.260	0.338
I8	1.335	-0.206
I19	1.547	0.305

* Missing data reduced the sample of this regression.

.1SA CPI Scale: Self Assurance X .1
CT30 Classroom Teacher Rating: Classifying questions
I8 Follow-up importance rating: leading discussions
I19 Follow-up importance rating: using different instructional modes

Table 3

Sample Means for Independent Variables Used in Decision Equations

Instructional Components			
Performance Objectives		Self-Analysis Skills	
Variable	$\overline{X}$	Variable	$\overline{X}$
CT18	4.53	.1SA	2.16
US18	4.48	CT30	4.34
.1CM	2.63	I8	4.28
CT35	4.52	I19	4.28
I10	3.93		

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